Data Visualization (DSC 530/CIS 602-02)

Multiple Views

Dr. David Koop
Interaction Overview

- Change over Time

- Select

- Navigate
  - Item Reduction
    - Zoom
      - Geometric or Semantic
    - Pan/Translate
  - Constrained

- Attribute Reduction
  - Slice
  - Cut
  - Project

[Munzner (ill. Maguire), 2014]
Animated Transitions

[http://bl.ocks.org/mbostock/3943967]
Animated Transitions

[http://bl.ocks.org/mbostock/3943967]
Selection

• Selection is often used to initiate other changes
• User needs to select something to drive the next change
• What can be a selection target?
  - Items, links, attributes, (views)
• How?
  - mouse click, mouse hover, touch
  - keyboard modifiers, right/left mouse click, force
• Selection modes:
  - Single, multiple
  - Contiguous? (all together in one region)
Highlighting

- Selection is the user action
- Feedback is important!
- How? Change selected item's visual encoding
  - Change color: want to achieve visual popout
  - Add outline mark: allows original color to be preserved
  - Change size (line width)
  - Add motion: marching ants
Highlighting

• Selection is the user action
• Feedback is important!
• How? Change selected item's visual encoding
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Navigation

Navigate

Item Reduction

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Attribute Reduction

- Slice

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- Project

[Munzner (ill. Maguire), 2014]
Geometric vs. Semantic Zooming

• Geometric zoom: like a camera
• Semantic zoom: visual appearance of objects can change at different scales

[http://bl.ocks.org/3680999 & http://bl.ocks.org/3680957]
Assignment 3

- Soccer data
  - Draw two choropleth maps
  - Draw a teammate graph using force-directed layout
  - Country lookup: Create an associative array, d3.map or Map
Exam 2

- Similar Format to Exam 1: Multiple Choice + Free Response
- Cumulative but emphasis on the topics covered since Exam 1
  - Geospatial Data
  - Color & Colormaps
  - Interaction
  - Multiple Views
- Reading: Ch. 8.1-8.3, Ch. 10, Ch. 6, Ch. 11, Ch. 12, Ch. 13
- Be prepared for a similar D3 question to the last exam
- Will cover research papers again
- More information to be made available on the course web page
Office Hours Tomorrow

• Scheduling conflict: **Tomorrow only**
• Hours for Tuesday, March 28: **12:30-2:30pm**
• Normal hours for Tuesday: 3-5pm
Multiple Views

- Why have just one visualization?
- Sometimes data is best examined in more than one view
  - Clutter/visual overload
  - Different attributes (cannot show all attributes in one view)
  - Different scales (task requires overview or detail)
  - Different encodings (no single encoding is optimal for all tasks)
- Eyes Beat Memory (Ch. 6)
  - Aiding working memory:
    - side-by-side/layers > animated > jump cuts
  - Showing all visual elements at once → don't need to remember
Multiple Views

- Big questions:
  - How to partition display or layer views?
  - How to coordinate views (e.g. navigation, selection)?
  - What data is shared?
Design Space of Composite Visualization

• Composite visualization views (CVVs)
  - Includes Coordinated multiple views (CMV)
  - + More!

• Design Patterns:
  - Juxtaposition: side-by-side
  - Superimposition: layers
  - Overloading: vis meshed with another
  - Nesting: vis inside a vis (recursive vis)
  - Integration: "merge" views + links

[W. Javed and N. Elmqvist, 2012]
Juxtaposition

[ComVis, K. Matkovic et al., 2008]
Juxtaposition
Juxtaposition Guidelines

• Benefits:
  - The component visualizations are independent and can be composed without interference
  - Easy to implement

• Drawbacks:
  - Implicit visual linking is not always easy to see, particularly when multiple objects are selected
  - Space is divided between the views, yielding less space for each view

• Applications: Use for heterogeneous datasets consisting of many different types of data, or for where different independent visualizations need to be combined.

[W. Javed and N. Elmqvist, 2012]
Integration

[Semantic Substrates, Schneiderin and Aris, 2006]
Integration

[VisLink, Collins and Carpendale, 2007]
Integration


Les nombres d’hommes portés sont representes par les larges des gorges celebre a raison d’un millieme pour 10000 hommes: les deux de plus etant en taille des gorges. Le trajet indique les homens qui rentrent en Russie, le reste ceux qui en partent... Les variations qui ont servi a dessiner la carte, on les prit dans les ouvrages de MM. Choper, de Beger, de Secot, de Chambray et le journal militaire de l’Armee depuis le 23 Octobre.

Pour mieux faire juger a l’avant la diminution de l’armee, j’ai represente que les corps du Prince de Noire et du Marechal Davout qui avaient detachees sur Mosk et Holdev a une region vers Orcha et Wilmy, uniss, toujours marche avec l’armee.

TABLEAU GRAPHIQUE de la temperature en degres du thermometre de Réaumur au dessous de zéro.

MOSCOU

(later known as a Sankey Diagram)

[Napoleon's March to Moscow, C. J. Minard, 1869]
Integration

"best statistical graphic ever"

(later known as a Sankey Diagram)

[Napoleon's March to Moscow, C. J. Minard, 1869]
Integration Guidelines

• Benefits:
  - Easy to perceive one-to-one and one-to-many relations between items in components
  - Visualizations are less independent compared to juxtaposed views, but still separate

• Drawbacks:
  - Extra visual clutter added to the overall view
  - Display space is split between the views
  - Some dependencies exist between views to allow for the visual linking

• Applications: Use for heterogeneous datasets where correlation and comparisons between views is particularly important.

[W. Javed and N. Elmqvist, 2012]
Superimposition

Figure 6: Mapgets (Superimposed Views). Presentation stack, with superimposed layers for rivers, borders, and labels, in Mapgets.

Figure 7: GeoSpace (Superimposed Views). A crime data layer superimposed on a geographical map of the Cambridge, MA area.

Superimposed views overlay two or more visual spaces on top of each other (Figures 6 and 7). The resulting visualization becomes the visual combination of the component visualizations, often using transparency to enable seeing all views. Superimposed views are generally used to highlight spatial relations in the component visualizations. In other words, the spatial linking present in these views is one-to-one, i.e., all the overlay visualizations share the same underlying visual space. Line graph visualizations with several data series, where more than one graph is superimposed in a single chart (e.g., [19]), is a very commonly used example of this design pattern.

The spatial linking in the superimposed views allows for easy comparison across different datasets because the user does not have to split their attention between different parts of the visual space. Furthermore, the fact that visualizations are stacked means that they can each use the full available space in the view. However, because the composition simply adds the component visualizations together, the visual clutter may become significant, and it is also likely to cause conflicts arising from one visualization occluding another.

5.1 Mapgets

Mapgets [38] is a geographic visualization system that allows users to interactively perform map editing and querying of geographical datasets. The maps generated using Mapgets are built on an underlying presentation stack that superimposes multiple dataset layers on top of each other. The users can dynamically select the dataset to use for each layer and the total number of layers to compose. Different layers in the presentation stack allow users to independently interact with each of the associated visualization and control the layer attributes. The technique also allows the users to reorder layers in the presentation stack to achieve the desirable map result. Figure 6 shows an example of a European map generated in Mapgets. The presentation stack associated with this map consists of three layers: the bottom layer visualizes rivers, the center layer is used to depict the country borders, and the topmost layer is used to display the country labels.

5.2 GeoSpace

GeoSpace [22] allows users to interactively explore complex visual spaces using superimposed views. It permits progressively overlaying different datasets, based on the user queries, in a single view. Beyond allowing users to explore datasets through dynamic queries, GeoSpace also supports pan and zoom operations for navigation. Figure 7 shows GeoSpace system being used for exploring crime around the Cambridge, MA area. The figure shows a 2D view of the visualization, where red dots that are spatially coupled to the underlying layer show the reported crime cases in the region.

Figure 8: SPPC [45] (Overloaded Views). This tool overloads points into the region bounded by two axes in the parallel coordinate plot.

Figure 9: Links on treemaps [14] (Overloaded Views). The tool identifies a tree structure in a graph and visualizes it using a treemap.
Superimposition

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[GeoSpace, I. Lokuge and S. Ishizaki, 1995]
Superimposition Guidelines

• Benefits:
  - Allows direct comparison in the same visual space.

• Drawbacks:
  - May cause occlusion and high visual clutter.
  - The client visualization must share the same spatial mapping as the host visualization.

• Applications: In settings where comparison is common, or where the component visualization views need to be as large as possible (potentially the entire available space).

[W. Javed and N. Elmqvist, 2012]
Overloading
Overloading

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[Links on Treemaps, J.-D. Fekete et al., 2003]
Overloading Guidelines

• Benefits:
  - The client visualization does not have to share the same coordinate space as the host visualization
  - This also yield more flexibility and control over visual clutter

• Drawbacks:
  - Visual clutter is increased
  - Visual design dependencies between components are significant

• Applications: Situations where one visualization can be folded into another to yield a compact (and complex) result.

[W. Javed and N. Elmqvist, 2012]
Nesting

<table>
<thead>
<tr>
<th>Nested Views</th>
<th>Overloaded Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;overlaying&quot;</td>
<td>&quot;overloading&quot;</td>
</tr>
</tbody>
</table>

One issue to discuss here is the difference between overloading and overlaying visual structures. Overloading involves sharing the visual space of the client visualization with the host visualization, while overlaying involves embedding the client visualization inside the host visualization. The nested views pattern provides an effective way of relating component visualizations, similar to overloaded views. This is effectively demonstrated in the figure, which shows a website exploration where the nested views pattern is used to visualize a website. The figure highlights how the nested views pattern is used to relate the component visualizations, similar to overloaded views.
Nesting

[NodeTrix, N. Henry et al., 2007]
Nesting Guidelines

• Benefits:
  - Very compact representation
  - Easy correlation

• Drawbacks:
  - Limited space for the client visualizations
  - Clutter is high
  - Visual design dependencies are high

• Applications: Situations that call for augmenting a particular visual representation with additional mapping

[W. Javed and N. Elmqvist, 2012]
Design Space

• Visualizations: the techniques or idioms used
• Spatial relation: relationship between visual structures in display space
• Data relation: visual relationship between items in different views
  - None: No relation
  - Item-item: One-to-one
  - Item-group: One-to-many
  - Item-dimension: Item in one view is a scale in another

[W. Javed and N. Elmqvist, 2012]
One such example is the use of interactive hyperlinking [6, 43] (or more visualizations, for example using interaction or animation. However, it is possible to envision other ways to combine two or more visualizations into one view. Such combinations are based solely on the spatial layout of component visualizations. The correct choice of design pattern to use for a particular implementation depends on different conditions, such as the available view space, user knowledge, and the complexity of the underlying dataset. Ideally, designers should be able to combine any existing visualizations to generate a composite visualization view.

### 8.2 Delimitations

Visualizations are nested inside its visual marks. The scatterplot visualization is acting as a host and bar graph visualizations based on this design pattern. In the figure, bar graph visualizations are nested inside its visual marks in the host.

by nesting clients inside the visual marks in the host. Dataset, visualized through client visualizations. This is achieved by nesting clients inside the visual marks in the host.

Also highlights the relational linking between the two datasets. In various ways, but also to suggest new combinations of visual representations that may significantly advance the state of the art.

We have proposed a novel framework for specifying, designing, and evaluating compositions of multiple visualizations in the same view space. Classifying existing techniques into patterns not only helps in understanding these techniques but also in evaluating their strengths and weaknesses.

Figure 12(e) shows an example composition of scatterplot and bar graph visualizations using different methods. This is achieved by nesting client visualizations inside the visual marks of the scatterplot visualization. This approach allows for the integration of information from different datasets in the same space and using different visualizations, but also highlights the relational linking between the two datasets.

### Summary

<table>
<thead>
<tr>
<th>Technique</th>
<th>Visualization A</th>
<th>Visualization B</th>
<th>Spatial Relation</th>
<th>Data Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComVis [24] (Figure 2)</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
</tr>
<tr>
<td>Improvise [39] (Figure 3)</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
</tr>
<tr>
<td>Jigsaw [36]</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
</tr>
<tr>
<td>Snap-Together [30]</td>
<td>any</td>
<td>any</td>
<td>juxtapose</td>
<td>none</td>
</tr>
<tr>
<td>semantic substrates [34] (Figure 4)</td>
<td>node-link</td>
<td>node-link</td>
<td>juxtapose</td>
<td>item-item</td>
</tr>
<tr>
<td>VisLink [11] (Figure 5)</td>
<td>radial graph</td>
<td>node-link</td>
<td>juxtapose</td>
<td>item-item</td>
</tr>
<tr>
<td>Napoleon’s March on Moscow [37]</td>
<td>time line view</td>
<td>area visualization</td>
<td>juxtapose</td>
<td>item-item</td>
</tr>
<tr>
<td>Mapgets [38] (Figure 6)</td>
<td>map</td>
<td>text</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
<td>GeoSpace [22] (Figure 7)</td>
<td>map</td>
<td>bar graph</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
<td>3D GIS [8]</td>
<td>map</td>
<td>glyphs</td>
<td>superimpose</td>
<td>item-item</td>
</tr>
<tr>
<td>Scatter Plots in Parallel Coordinates [45] (Figure 8)</td>
<td>parallel coordinate</td>
<td>scatterplot</td>
<td>overload</td>
<td>item-dimension</td>
</tr>
<tr>
<td>Graph links on treemaps [14] (Figure 9)</td>
<td>treemap</td>
<td>node-link</td>
<td>overload</td>
<td>item-item</td>
</tr>
<tr>
<td>SparkClouds [21]</td>
<td>tag cloud</td>
<td>line graph</td>
<td>overload</td>
<td>item-item</td>
</tr>
<tr>
<td>ZAME [13] (Figure 10)</td>
<td>matrix</td>
<td>glyphs</td>
<td>nested</td>
<td>item-group</td>
</tr>
<tr>
<td>NodeTrix [17] (Figure 11)</td>
<td>node-link</td>
<td>matrix</td>
<td>nested</td>
<td>item-group</td>
</tr>
<tr>
<td>TimeMatrix [44]</td>
<td>matrix</td>
<td>glyphs</td>
<td>nested</td>
<td>item-group</td>
</tr>
<tr>
<td>GPUVis [25]</td>
<td>Scatterplot</td>
<td>glyphs</td>
<td>nested</td>
<td>item-group</td>
</tr>
</tbody>
</table>

### Table 1: Classification of common composite visualization techniques using our design space.

The benefit is high, and visual design dependencies are high. Again, situations that call for augmenting a particular visual representation with additional mapping.

Applications:

- Very compact representation, easy correlation.

Drawbacks:

- Limited space for the client visualizations, clut

Benefits:

- Very compact representation, easy correlation.
Summary (Scatterplot + Bar Chart)

(a) Juxtaposed views.  (b) Integrated views.  (c) Superimposed views.

(d) Overloaded views.  (e) Nested views.

[W. Javed and N. Elmqvist, 2012]
Multiple Views

• Facet (noun and verb)
  - particular aspect or feature of something
  - to split

• Partition visualization into views/layers
  - Either juxtapose (side-by-side), superimpose (layer), nest, etc.
  - Depends on data and encoding
  - Generally, superimposing does not scale as well
  - Multiple views eats display space (either large screens or small visualizations)
Multiple Views

- Juxtapose and Coordinate Multiple Side-by-Side Views

- Share Encoding: Same/Different
  - Linked Highlighting

- Share Data: All/Subset/None

- Share Navigation

[Munzner (ill. Maguire), 2014]
## Multiple Views

<table>
<thead>
<tr>
<th>Encoding</th>
<th>Data</th>
<th>All</th>
<th>Subset</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>Redundant</td>
<td>Overview/Detail</td>
<td>Small Multiples</td>
<td></td>
</tr>
<tr>
<td>Different</td>
<td>Multiform</td>
<td>Multiform, Overview/Detail</td>
<td>No Linkage</td>
<td></td>
</tr>
</tbody>
</table>
Multiform

[Improvise, Weaver, 2004]
Multiform Views

• The same data visualized in different ways
• Does not need to be a totally different encoding (all choices need not be disjoint), e.g. horizontal positions could be the same
• One view becomes cluttered with too many attributes
• Consumes more screen space
• Allows greater separability between channels
Small Multiples

• Same encoding, but different data in each view (e.g. SPLOM)

[http://bl.ocks.org/mbostock/4063663]
Interaction with Multiform & Small Multiples

• Key interaction with multiform and small multiples: **brushing**
  - also called linked highlighting

• Want to understand correspondences between representation in the different views
Brushing

[http://bl.ocks.org/mbostock/4063663]
Schneiderman's Mantra

• Visual Information-Seeking Mantra [B. Schneiderman, 1996]:
  - Overview first
  - Zoom and filter (Chapter 13)
  - Details on demand

• Goal of the overview is to **summarize** all of the data

• Want specific **details** about some aspect(s) of the data, need another view/layer
  - May be permanent: side-by-side
  - May be a popup layer: often opaque or separated

• (see textbook Ch. 6.7)
Overview-Detail View

[Wikipedia]
Overview-Detail (Different Encoding)

EXPENDITURES BY FUNCTION (BAR & DONUT)

- Academic Support
- Auxiliary Enterprises
- Depreciation and Amortization
- Impairment of Capital Assets
- Institutional Support
- Instruction
- Interest
- Medical Centers
- Operation and Maintenance of Plant
- Other
- Public Service
- Research
- Student Financial Aid
- Student Services

EXPENDITURES BY CAMPUS FY 2012 reset

FIVE-YEAR TREND

Overview-Detail (with Zoom-Filter)

• Detail involves some subset of the full dataset
• Involves user selection or filtering of some type

• How question: includes facet
• Examples:
  - Maps: partition into two views with same encoding, overview-detail
  - UC Trends: partition into multiple views, coordinated with linked highlighting, overview+detail of expenditures
Multiform & Small Multiples (Cerebral)
Navigation across multiple views

- Often navigation in one view updates navigation in another
- Example: Maps: overview shifts as you move around in detail view
- Selections in one view may trigger selections in another
Multiple Views

Partition into Side-by-Side Views

Superimpose Layers

[Munzner (ill. Maguire), 2014]
Partitioned Views

• Split dataset into groups and visualize each group
• Extremes: one item per group, one group for all items
• Can be a hierarchy
  - Order: which splits are more "related"?
  - Which attributes are used to split? usually categorical
Glyphs, Views, and Regions

- Glyphs are composed of multiple marks
- Views are a contiguous region of space
- A region is usually associated with a group of data
- Blurry lines of distinction between them
Example: Grouped Bar Chart

[Example Chart]

[M. Bostock, http://bl.ocks.org/mbostock/3887051]
Example: Small Multiples Bar Chart

[M. Bostock, http://bl.ocks.org/mbostock/4679202]
Matrix Alignment & Recursive Subdivision

- **Matrix Alignment:**
  - regions are placed in a matrix alignment
  - splits go to rows and columns
  - main-effects ordering: use summary statistic to determine order of categorical attribute

- **Recursive subdivision:**
  - Designed for exploration
  - Involves hierarchy
  - User drives the ways data is broken down in recursive manner
I page. In Figure 2 there are 6 panels, 1 column, 6 rows, and 1 page. Later, we will show a Trellis display with more than one page. We refer to the rectangular array as the trellis because it is reminiscent of a garden trelliswork.

Each panel of a trellis display shows a subset of the values of panel variables; these values are formed by conditioning on the values of conditioning variables. In Figure 1 the panel variables are variety and yield, and the conditioning variables are site and year. On each panel, values of yield and variety are displayed for one combination of year 20, 30, 40, 50, 60, and variety: Trebi, Wisconsin No. 38, No. 457, Glabron, Peatland, Velvet, No. 475, Manchuria, No. 462, Svanosota.
Example: HiVE System

[Slingsby et al., 2009]
Example: HiVE System

[Slingsby et al., 2009]